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Optimization of spawning rates and substrate-supplement combinations for enhanced yield and quality of *Pleurotus* spp. in Eastern Uttar Pradesh

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Abstract

The cultivation of oyster mushrooms (*Pleurotus* spp.) is an increasingly significant agro-industry in India due to its high nutritional value, low input costs, and ability to utilize agricultural waste. This research was undertaken to evaluate the effect of varying spawning rates and different substrate-supplement combinations on the yield and quality of *Pleurotus* species under the climatic conditions of Eastern Uttar Pradesh. Five *Pleurotus* species, namely *P. sajor-caju*, *P. florida*, *P. djamor*, *P. cornucopiae*, and *P. ostreatus*, were studied. The spawning rates tested included 2%, 4%, 6%, 8%, and 10% based on the dry weight of the substrate. In parallel, twelve combinations of substrates (wheat straw, paddy straw, corn cob) and organic supplements (cottonseed cake, wheat bran, legume husk) were analyzed for their effect on yield and biological efficiency.

The results revealed that a 6% spawning rate yielded the best performance in terms of both yield and biological efficiency, balancing colonization time and resource use. Among the substrate combinations, soybean straw supplemented with cottonseed cake showed the highest productivity, followed closely by cotton stalks supplemented with legume husk. These findings suggest that optimal spawning and substrate strategies can significantly enhance the profitability and sustainability of mushroom cultivation in subtropical regions. The research offers valuable insights and practical recommendations for farmers and commercial cultivators aiming to improve the efficiency and quality of oyster mushroom production.

Keywords: *Pleurotus* spp., oyster mushroom, spawning rate, substrate-supplement combination

Introduction

Oyster mushrooms, belonging to the genus *Pleurotus*, are edible fungi known for their delicate flavor, high protein content, and efficient growth on a wide range of lignocellulosic substrates. Globally, they rank among the most cultivated mushrooms due to their relatively simple cultivation requirements and their capacity to convert agricultural wastes into protein-rich food. In India, particularly in Eastern Uttar Pradesh, the cultivation of *Pleurotus* mushrooms is emerging as an important source of income and nutrition, especially for small and marginal farmers.

The success of mushroom cultivation depends on several critical agronomic factors, of which the spawning rate and substrate quality are paramount. The spawn rate refers to the quantity of mushroom spawn (mycelium inoculum) introduced into the substrate. An optimal spawn rate ensures rapid colonization, reduces the risk of contamination, and maximizes yield. However, excessively high spawn rates can lead to economic inefficiency and overheating of the substrate, thereby reducing mushroom quality. Conversely, low spawn rates may prolong colonization and increase the risk of microbial competition.

Equally important is the choice of substrate and its supplementation. Agricultural by-products such as wheat straw, paddy straw, and corn cobs serve as excellent substrates for *Pleurotus* spp. cultivation due to their availability and composition. However, their nutrient profile can be significantly enhanced through the addition of organic supplements like cottonseed cake, legume husk, and wheat bran. These supplements improve the carbon-to-nitrogen (C:N) ratio of the substrate, thereby promoting robust mycelial growth and higher biological efficiency.

Despite the recognized importance of these factors, there is a lack of standardized guidelines tailored to the agro-climatic conditions of Eastern Uttar Pradesh. Most farmers rely on generalized practices that may not yield optimal results in local conditions. This study aims to fill this gap by systematically investigating the impact of different spawning rates and substrate-supplement combinations on the yield and biological efficiency of *Pleurotus* spp. The findings are expected to offer region-specific cultivation strategies that enhance productivity and ensure sustainable utilization of agricultural waste.

Materials and Methods

Study Area and Duration

The experimental study was conducted at the Mushroom Cultivation Unit, Department of Plant Pathology, Shri Durga Ji Post Graduate College, Chandeshwar, Azamgarh, Uttar Pradesh, India. The site is situated in a subtropical region at an elevation of 64 meters above mean sea level. The experimental trials were carried out during two seasonal periods: February to April 2022 (spring season) and October to December 2023 (autumn season), to account for climatic variation and its influence on mushroom growth.

Mushroom Species and Culture Maintenance

Five species of oyster mushrooms were selected for the study: *Pleurotus sajor-caju*, *P. florida*, *P. djamor*, *P. cornucopiae*, and *P. ostreatus*. The cultures were procured from the Mushroom Research and Training Centre (MRTC), G.B. Pant University of Agriculture and Technology, Pantnagar. These cultures were maintained on potato dextrose agar (PDA) media and stored under refrigeration until further use.

Spawn Preparation

Spawn was prepared using healthy, unbroken wheat grains. The grains were first soaked overnight and then boiled for 15-20 minutes to soften. After draining excess water, 3% calcium carbonate was added to adjust the pH and prevent clumping. The treated grains were packed into sterilized polypropylene bags and autoclaved at 20 psi for 20 minutes over two consecutive days. After cooling, the bags were inoculated with mycelial culture under aseptic conditions inside a laminar airflow cabinet and incubated at 24 ± 2°C for 12-15 days to obtain fully colonized master spawn.

Experimental Design

A Completely Randomized Design (CRD) was used for the experiment, with three replications per treatment. Two sets of experiments were carried out:

- 1. To determine the effect of different spawning rates (2%, 4%, 6%, 8%, and 10% w/w of dry substrate) on mushroom yield.
- 2. To identify the most effective substrate and supplement combinations from twelve treatments involving different substrates (wheat straw, paddy straw, corn cob) and supplements (cottonseed cake, wheat bran, legume husk).

Substrate Preparation and Supplementation

The selected substrates were chopped into 2-3 inch pieces, soaked in water overnight, and pasteurized using a solution of 75 ml formaldehyde (37-40%) and 5 g carbendazim in 100 liters of water. The soaked and pasteurized substrate was left covered for 18 hours and then drained. Supplements were added to the substrate at a 5% rate (w/w), thoroughly mixed, and the final moisture content was adjusted to 65-70% before spawning.

Cultivation and Monitoring

The substrate-spawn mixtures were filled into polythene bags with aeration holes and incubated in a dark room for the spawn run phase. The temperature during incubation was maintained between 22-26 °C with 60-65% relative humidity. Once fully colonized, the bags were opened and shifted to a cropping room for fruiting. The cropping room was maintained at 75-85% humidity, with adequate ventilation and diffused light.

Observation Parameters

The following parameters were recorded:

- Spawn run completion time (days)
- Days to pinhead initiation
- Number of pinheads
- Days to first harvest
- Number of fruiting bodies
- Yield per bag (g)
- Total yield over 3 flushes (g)
- Biological Efficiency (%)

Biological efficiency was calculated using the formula:
Biological Efficiency (%) = (Fresh Weight of Mushrooms / Dry Weight of Substrate) x 100

Results

Effect of Spawning Rates on Yield and Biological Efficiency

The analysis of different spawning rates revealed significant differences in yield and biological efficiency across all five *Pleurotus* species. The 6% spawning rate consistently produced the highest yield and biological efficiency, with average values reaching up to 975 g per kg of dry substrate and a biological efficiency of 97.5%. Lower spawning rates such as 2% and 4% showed slower colonization, delayed pinhead initiation, and lower fruiting body formation. In contrast, spawning rates beyond 6% (i.e., 8% and 10%) did not result in proportionally higher yields and in some cases caused substrate overheating, which adversely affected the quality and size of mushrooms.

Table 1: Spawning Rates on Yield and Biological Efficiency

Spawning Rate (%)	Yield (g)	Biological Efficiency (%)
2%	700	70
4%	850	85
6%	975	97.5
8%	940	94
10%	900	90

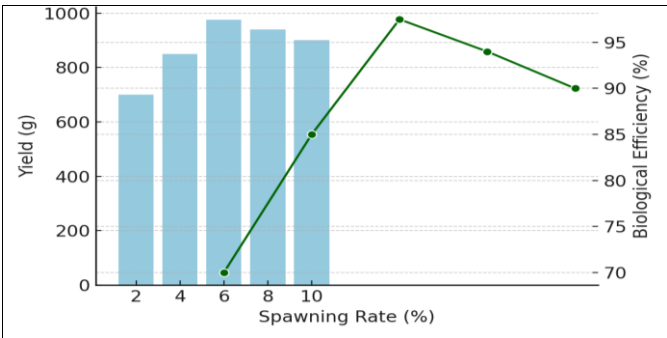


Fig 1: Spawning Rates on Yield and Biological Efficiency

Among the species, *P. sajor-caju* and *P. florida* demonstrated superior performance at the 6% spawning rate, exhibiting rapid mycelial colonization and uniform fruiting. *P. djamor* and *P. cornucopiae* responded well under moderate spawn rates but

showed variability in yield at higher doses. These results highlight the importance of optimizing spawn dosage to avoid unnecessary input costs while maximizing yield outcomes.

Performance of Substrate and Supplement Combinations

The yield and biological efficiency of *Pleurotus* spp. were also significantly influenced by substrate type and supplement used. Among the twelve tested combinations, soybean straw supplemented with cottonseed cake emerged as the most effective, yielding over 1025 g per kg of dry substrate and achieving a biological efficiency of 102.5%. Cotton stalks with legume husk supplementation also performed well, yielding approximately 980 g/kg and 98% biological efficiency.

Table 2: Summarizes the comparative performance of selected substrate and supplement treatments

Substrate Combination	Supplement Used	Yield (g/kg)	Biological Efficiency (%)
Soybean + Wheat Straw	Cottonseed Cake	1025	102.5
Cotton Stalks	Legume Husk	980	98.0
Paddy Straw	Wheat Bran	950	95.0
Wheat Straw	No Supplement	800	80.0

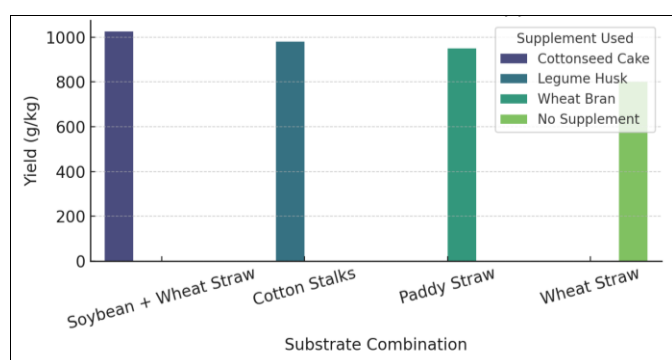


Fig 2: Comparative performance of selected substrate and supplement treatments

Wheat straw and paddy straw supplemented with wheat bran offered moderate yields ranging from 850-950 g/kg. Unsupplemented wheat straw produced the lowest yield of 800 g/kg with a biological efficiency of 80%. The addition of nitrogen-rich organic materials such as cottonseed cake and legume husk enhanced substrate quality, providing essential nutrients that promoted vigorous mycelial growth and increased sporophore formation.

The combination of soybean straw with cottonseed cake not only improved yield but also shortened the spawn run and fruiting cycles, making it a highly suitable option for commercial cultivation. Furthermore, these materials are readily available in Eastern Uttar Pradesh, supporting cost-effective and sustainable mushroom farming in the region.

Discussion

The present study underscores the critical role that optimized agronomic practices specifically spawning rate and substrate formulation play in enhancing oyster mushroom productivity. The results clearly demonstrate that a spawning rate of 6% offers the most favorable balance between mycelial colonization speed, yield, and biological efficiency. While it is intuitive to assume that higher spawning rates might accelerate growth, this study reveals diminishing returns beyond a certain threshold, particularly due to the overheating and premature nutrient exhaustion in the substrate observed at 8% and 10% levels.

These findings align with previous literature suggesting that overly high spawn doses can lead to metabolic stress within the substrate microenvironment.

The superior performance of *P. sajor-caju* and *P. florida* under 6% spawn rate indicates their adaptability and vigorous colonization abilities under optimal conditions. Their robust mycelial networks likely enabled better substrate decomposition and nutrient absorption, which translated into higher yields and efficiency.

Equally revealing are the outcomes from the substrate-supplement experiments. The synergistic effect of soybean straw and cottonseed cake demonstrates that substrates rich in lignocellulose, when paired with nitrogen-rich organic amendments, can significantly boost mushroom biomass. The addition of cottonseed cake not only improved the C:N ratio but also introduced micronutrients that supported vigorous fungal metabolism. This reflects the broader principle that the nutritional quality of the substrate is a limiting factor in saprophytic mushroom cultivation.

The findings also have socio-economic implications. Soybean straw and cottonseed cake are commonly available in Eastern Uttar Pradesh, making them both accessible and affordable for local farmers. The study therefore offers a region-specific, low-cost cultivation model that can be adopted widely to increase rural incomes and promote agro-waste recycling.

Conclusion

This study successfully establishes a scientific basis for optimizing oyster mushroom cultivation through two vital agronomic strategies: spawning rate and substrate-supplement integration. The identification of 6% spawning rate as the optimal level for maximizing yield and biological efficiency provides a practical and economical standard for *Pleurotus* spp. cultivation under subtropical conditions. This recommendation minimizes resource wastage while accelerating colonization and fruiting timelines, ultimately enhancing productivity.

The evaluation of substrate and supplement combinations revealed that soybean straw supplemented with cottonseed cake significantly boosts yield and biological efficiency, validating the role of nutrient-rich organic matter in augmenting mushroom production. These findings not only promote higher profitability for mushroom growers but also encourage the use of locally available agro-wastes, thereby contributing to environmental sustainability and circular agriculture.

Taken together, the research outcomes offer scalable and regionally adaptable solutions for improving the efficiency, quality, and economic viability of oyster mushroom farming. Future work may explore the influence of micronutrient enrichment, microbial inoculants, and post-harvest quality traits to further refine the best practices for sustainable mushroom cultivation.

Recommendations

1. Farmers in Eastern Uttar Pradesh and similar agro-climatic regions should adopt a 6% spawning rate for *Pleurotus* spp. cultivation to achieve maximum yield and biological efficiency with minimal resource input.
2. Soybean straw supplemented with cottonseed cake is recommended as the most productive and cost-effective substrate combination. Its use can substantially increase both biological efficiency and harvest frequency.
3. Farmers should consider locally available agro-wastes like cotton stalks and legume husks as viable alternatives for supplementation, which also contributes to waste recycling.

and sustainability.

4. Training programs should be organized to disseminate best practices for substrate sterilization, spawn preparation, and environmental control during cultivation to improve quality and reduce contamination.
5. Further research should explore the use of microbial bio-enhancers, micronutrient fortification, and post-harvest preservation techniques to increase shelf life and market value of mushrooms.
6. Government and NGOs are encouraged to support mushroom cultivators by facilitating access to high-quality spawn, providing market linkage opportunities, and promoting mushroom cooperatives for better economic outcomes.

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